11.—Effect of Salt, Temperature and Seed Scarification on Germination of Two Varieties of Arthrocnemum halocnemoides

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Green, but ripe seed heads of *Arthrocnemum halocnemoides* varieties *pterygosperma* and *pergranulatum* were collected and dried and the resulting seeds germinated well.

Germination of both varieties was tested in solutions containing nil, 0.8, 1.6 and 2.4 per cent sodium chloride. Tests were carried out in a factorial experiment at eight temperature regimes. Salinity caused reduction and delay in germination of both varieties. 50 per cent reduction in germination of *var. ptergosperma* occurred at about 8 g/l NaCl and of *var. pergranulatum* at about 20 g/l NaCl. Salinity and temperature interacted in their effects on germination.

Var. pterygosperma gave significant germination only at 5-35°C the temperature range at which *var. pergranulatum* gave best germination.

Scarified and unscarified seed of *var. pergranulatum* was tested at six temperature regimes. Scarification caused an increase and an acceleration of germination. There was an interaction between scarification and temperature.

Introduction

Extensive areas of land in the agricultural areas of Western Australia are too highly saline for the growth of normal crops. As reported by Burvill (1956), in the results of a statistical survey, farmers in Western Australia estimated that in 1955 there were 933,000 acres of salty Samphire (*Arthrocnemum spp.*) flats or Ti-tree (*Melalenca spp.*) flats on their farms in the agricultural areas. This land is described by Smith (1961, 1961a) as "valley water-logged" and has an extremely salty watertable of 1,000 to 4,000 grains per gallon total soluble salts, closer to the surface than 4 ft.

Smith and Malcolm (1959) discussed the use of *Kochia brevifolia* and *Atriplex spp.* for growing on salt affected soils but the plants were not recommended for waterlogged areas. In seeking plants for waterlogged salty areas, the naturally occurring *Arthrocnemum spp.* have been investigated. The germination studies reported here are part of a programme of research into the use of *Arthrocnemum spp.* for sowing as fodder plants on highly saline winter waterlogged soils.

Seedheads of most plants dry off or ripen at some stage in their life cycle. The seed may then be harvested. In *A. bidens*, the seed heads are retained in a dried and woody condition. However, in *A. halocnemoides* varieties *pergranulation* and *pterygosperma* the seed heads, or inflorescences, may remain green and fleshy for several months after the seed has apparently ripened. As a result the opportunity for the inflorescences to dry off passes with the passing of summer. Green inflorescences were collected, air dried in the laboratory, and seed obtained by threshing and cleaning. The resulting seed germinated well and was used in the trials reported in this paper.

In some preliminary attempts at germinating seed of *Arthrocnemum spp.* in the laboratory it became clear that several factors were operative. Scarification appeared to assist germination of seed of *A. halocnemoides var. pergranulatum* and temperature seemed to influence germination of *var. pterygosperma*. The germination trials discussed in this paper were designed to elucidate these effects and to study the effects of salt, a factor of considerable importance in the natural habitat of the species.

Method

(i) Effect of temperature and salt on the germination of *A. halocnemoides* varieties *pergranulatum* and *pterygosperma*

The salinity treatments, nil, 0.8, 1.6 and 2.4 per cent, sodium chloride, were imposed by placing the seeds in 15 mls of the appropriate solution in a petri dish. The solutions were pipetted off and replaced at regular intervals to avoid concentration effects due to evaporation.

The temperature regimes were as follows:

20°C. constant	5-35°C. fluctuating
30°C. ,,	15-30°C. ,,
35°C. ,,	15-45°C. ,,
60°C. ,,	15-60°C. ,,

The fluctuating temperatures were thermostatically controlled to give gradual changes simulating normal day-night fluctuations as described by Quinlivan (1962).

The temperature and salinity treatments were combined factorially and three 50 seed replications were tested at each combination.

Germination was counted at 2-4 day intervals over the duration of the trial which lasted for 33 days. Germination was taken to have commenced when the radical emerged from the testa.

(ii) Effect of Temperature and Scarification on Germination of *A. halocnemoides var. pergranulatum*

The following temperature regimes were used:

35°C. constant	5-35°C. fluctuating
60°C. ,,	15-30°C. ,,
	15-45°C. ,,
	15-60°C. ,,

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For each temperature three replications each of scarified and unscarified seed were tested. The scarification was applied at random to seedlots, after they had been counted, by lightly rubbing with fine emery paper.

Germination was counted at regular intervals over the duration of the trial which lasted for 28 days.

Results

(i) Effect of temperature and salt

Both temperature and salinity caused marked effects on germination (Table 1). *Var. pterygosperma* gave significant germination only in the 5-35°C. temperature treatment. *Var. pergranulatum* also showed a preference for the 5-35°C. range, but gave some germination at other temperatures.

A constant temperature of 60°C. gave rapid germination with *var. pergranulatum*, and seven days from the commencement of the trial the germination figures shown had been reached. No germination occurred thereafter. It appeared that the high temperature had broken the dormancy of the seed but caused a high mortality rate. By contrast seed in the 5-35°C. range did not commence to germinate until seven days had passed but reached a final percentage of 75 as against 36 per cent. for the 60°C. treatment.

There was an interaction between temperature and salinity effects similar to that shown by Malcolm (1963) for *Kochia brevifolia*. While 0.8 per cent. NaCl caused no reduction in germination of *var. pergranulatum* at 5-35°C., at 60°C. it caused a reduction from 36 to 25 per cent. germination. Similarly, 1.6 per cent. NaCl caused a reduction from 75 to 52 per cent. (31 per cent reduction) in germination of *var. pergranulatum* at 5-35°C., but at 60°C. a reduction of from 36 to 13 per cent. (64 per cent. reduction) was caused. Thus, in each case salinity and a temperature of 60°C. interacted to give greater reductions in germination than was shown for either factor operating separately.

TABLE 1

Effect of temperature and salt on germination of two varieties of Arthrocnemum halocnemoides

(mean per cent. germination from 3 replications of 50 seeds)

Variety	pterygosperma				pergranulatum			
Salinity	0	0·8	1·6	2·4	0	0·8	1·6	2·4
Germination 14 days after commencement of experiment								
Temperature °C. :								
20	1	1	0	0	0·3	0	0	0
30	1	0	0	0	0	0	0	0
35	1	1	0	1	7	3	3	1
60	0	1	0	0	36	18	11	0
5–35	7	4	0	1	28	17	3	0
15–30	3	1	0	0	1	3	1	0
15–45	1	1	0	0	6	1	1	0
15–60	1	1	0	0	10	6	1	1
Final Germination 33 days after commencement of experiment								
Temperature °C. :								
20	1	3	0	0	1	1	0	0
30	1	0	0	0	0	1	0	0
35	1	1	0	1	8	4	3	1
60	0	1	0	0	36	25	13	3
5–35	72	37	15	2	75	75	52	0
15–30	4	1	0	0	4	5	5	0
15–45	1	1	1	0	10	3	1	0
15–60	1	1	0	0	20	13	1	1

Three temperature factors appear to influence germination. As discussed, high temperature accelerates germination of *var. pergranulatum*, though similar effects were not noted for *var. pterygosperma*. The effect of high temperature is shown in the germination of *var. pergranulatum* in the progressive increase in germination through the 15-30°C., 15-45°C., and 15-60°C. ranges. High temperature failed to affect germination of *var. pterygosperma*.

A second factor operating is temperature fluctuation, the effect of which is most clearly seen in the results for *var. pterygosperma*. While constant temperatures of 20, 30 and 35°C. gave almost no germination, a fluctuating temperature of 5-35°C. gave 72 per cent. germination.

Finally a relatively cold temperature is required by both varieties as the minimum temperature in the fluctuating range. Ranges of 15-30, 15-45, and 15-60°C. gave almost no germination with *var. pterygosperma* but a range of 5-35°C. gave high germination. The range 15-45°C. is of the same magnitude, 30 degrees, as the 5-35°C. range but does not include a sufficiently cold temperature. *Var. pergranulatum* gave similar results but effects of high temperature caused a variation. It is of interest to note that germination of both varieties occurred in the glasshouse where the temperature range was approximately 10-31°C.

The specific temperature requirements indicate dormancy problems. The response to the 60°C. treatment suggests hard-coatedness (see below). The response to fluctuating temperatures and to a relatively cold temperature e.g. 5 or 10°C. may be due in part to hard-coatedness and partly to physiological dormancy.

(ii) Effect of Temperature and Scarification

In this trial, the effects of temperature were similar to those discussed under Section (i), but varied in the effect of high temperature. 60°C. constant and 15-60°C. fluctuating temperatures failed to give comparable figures. The reason for this is not known but may have been due to the use of a different batch of seed.

Scarification caused a marked increase and acceleration in germination. For the 5-35°C. range unscarified seed gave a germination of 43 per cent., but scarified seed gave 64 per cent. germination. In the 15-45°C. range the difference was even greater, 11 per cent. germination being obtained without scarification and 46 per cent. with scarified seed.

Scarification resulted in reasonable germination being obtained at temperatures which normally gave very poor results. For example 35°C. germination without scarification was 9 per cent. but with scarification was 36 per cent.

Seed which had been scarified gave 34 per cent. germination by the end of 13 days testing at 15-45°C. but unscarified seed had only given 5 per cent. germination over this period. The large difference was due in part, to the accelerating effect of scarification.

It is likely the scarification treatment was not even on all seeds in view of the difficulty of scarifying such tiny seeds in a controlled manner. The seeds are encased in a hard black testa and scarification was continued until the

TABLE 2

Effect of temperature and scarification on germination of *A. halocnemoides* var. *pergranulatum* (mean per cent. germination from 3 replications of 50 seeds each)
(commenced 11.x.63)

Date	Scarified						Unscarified					
	Temp. C.						Temp. C.					
	35	60	5-35	15-30	15-45	15-60	35	60	5-35	15-30	15-45	15-60
14.x.63	0	0	0	1	3	6	0	0	0	0	0	0
16.x.63	5	3	0	2	10	9	0	1	0	1	2	1
17.x.63	7	3	1	2	17	10	0	1	3	1	3	1
21.x.63	9	3	16	7	25	11	2	1	3	1	3	2
24.x.63	12	4	23	9	34	12	3	1	4	3	5	3
28.x.63	33	5	32	11	39	13	5	1	13	5	7	4
31.x.63	36	11	55	16	45	15	9	4	39	7	10	5
6.xi.63	36	11	64	17	46	17	9	5	43	7	11	6
8.xi.63	36	11	64	17	46	17	9	5	43	7	11	6

majority of seeds in the sample bore light coloured patches. The variations are accounted for in the design of the experiment.

Discussion

(i) Effect of temperature and salt

Novikoff (1946) reported 50 per cent. reduction in germination for several vegetable crops to occur at 18-22 gm/l NaCl. Malcolm (1963) found that for *Kochia brevifolia* 50 per cent. reduction in germination occurred at 15-20 gm/l NaCl. In the present study, *var. pterygosperma* gave 50 per cent. reduction in germination at about 8 gm/l NaCl, and *var. pergranulatum* probably at about 20 gm/l NaCl. It may be concluded that from the point of view of salt tolerance at germination, *var, pergranulatum* is similar to many vegetable crops and *var pterygosperma* is less tolerant.

The results indicate that temperature is a vital factor determining when *A. halocnemoides* will germinate. Moreover, germination will not occur when the salinity of the soil solution is greater than 2.4 per cent. NaCl. Smith (1961a) reported seasonal changes in salinity of a bare soil at Quairading. *Arthrocnemum spp.* are growing nearby. The lowest value obtained for the 0-¼ inch samples was 0.80 per cent. NaCl on the oven dry basis in July and the average for the July sampling was 1.11 per cent. NaCl. The soil in question was a fine sandy clay loam. The combination of low winter temperatures and high salinity would provide a severe limitation to the germination of the varieties under study. It is apparent that the plants have developed a means of avoiding germination into too harsh an environment. A great deal of rain would be required to leach salts from the topsoil sufficiently to allow germination to occur.

The results indicate that field planting of the species could be undertaken in the autumn before rain makes the soil unworkable, and the seeds would germinate when conditions become favourable. Salt tolerance of the seedlings must increase extremely rapidly and early in life surpass that of most other plants.

(ii) Effect of Temperature and Scarification

The scarification treatment was more effective in breaking dormancy than the best temperature regime under test, but still did not ensure good germination at unfavourable temperatures. On the other hand the seed coat appears to be slowly permeable on at least a proportion of seeds—those which germinate at 5-35°C. without scarification. Scarification allows the slowly permeable seeds to germinate more rapidly and allows further impermeable seeds to germinate.

Assuming the main effect of scarification is to allow water to gain ready access to the seed, an interaction can be shown between scarification and temperature. Germination of scarified seed can be considered as the potential germination for each temperature range. Leaving seed unscarified would be expected to cause the same proportional decrease in germination at all temperatures. However, at 15-45°C. the germination of unscarified seed amounted to 11 per cent, about one quarter that for scarified seed. Whereas at 5-35°C. unscarified seed gave 43 per cent. germination, about two thirds that for scarified seed. The 5-35°C. temperature range appears to influence the permeability of the seed coat in some way and make up for non-scarification.

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12.—Ashbed and Nutrients in the Growth of Seedlings of Karri (Eucalyptus diversicolor F.v.M.)

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When karri seedlings were grown in pots of soils from karri forest areas they showed remarkable responses to nitrogen and phosphorus fertilizers. The addition of nitrogen or phosphorous fertilizers separately gave only small increases in yield of seedlings, while the simultaneous addition of both fertilizers gave very large responses (up to three-fold in height and twenty-fold in dry weight).

Responses to ash and to heat treatment of the soil were also obtained. The major part of the ash response was shown to be due to the supply of phosphorus in the ash. The heat response is also believed to be largely due to increased supply of nutrients.

It is suggested that part of the well known ashbed response of karri forests is due to nutrients released in the ashing process.

Introduction

Growth of karri *(Eucalyptus diversicolor* F.v.M.) seedlings in the south-west of Western Australia is stimulated considerably in ashbeds where heaps of forest slash have been burned (Loneragan, 1961). Growth of young karri seedlings in non-ashbed areas is generally so poor that deliberate creation of ashbeds has become part of karri forest regeneration practice.

Karri ash contains plant nutrients including phosphorus, calcium, magnesium, and potassium (Stoate, 1950; Hatch, 1960) which may be important in the ashbed response. However, other marked chemical and physical changes are associated with ashbed treatment (Hatch, 1960) and no nutrient responses of karri have been recorded.

The work described in this paper was undertaken to assess nutrient deficiencies of a number of karri soils for optimum growth of karri seedlings, and to see to what extent nutrients might account for some of the stimulating effects of ashbeds.

Methods

Experiments 1, 2, 3.

General.—A red-brown sandy loam (karri-type) soil was taken from an area which showed typical ashbed response in regenerating karri seedlings at Crowea, 20 miles south of Manjimup. Soil from the top six inches was sieved, mixed, and 3,000 g placed in plastic bags in unglazed earthenware containers of 8-inch diameter at the surface.

All fertilizer additions are expressed as weight/acre calculated from a surface area basis (1 cwt/acre = 0.405g/pot). The plastic bags were perforated so that the soil was freely drained. The pots of soil were kept in the open at the Forests Department, Manjimup.

Karri *(Eucalyptus diversicolor)* seeds were sown in all pots on August 11 and 12, 1961. Natural rain was supplemented by de-ionised water as required. Plants were thinned to 5 per pot on October 2, to 3 per pot on October 30, and to 1 per pot on December 6.

The heights of plants from cotyledonary node to growing point was measured at frequent intervals throughout the experiment: data in tables refer to heights on April 26, about two weeks prior to harvest. At this time the thickness of the stem just above the cotyledonary node was also measured with calipers.

Shoots and roots of plants of experiments 1 and 3 were separated at the cotyledonary nodes and harvested on May 4 and 3, 1962, respectively: plants of experiment 2 were not harvested.

Harvested material was dried in an oven at 105°C, cooled in a desiccator, and weighed.

Detail.—*Experiment 1*—To test the effects of nutrients on the ashbed response of karri seedlings on karri-type soil.

No basal fertilizers were applied. Treatments were applied in quadruplicate, in a 2 x 2 x 2 factorial design as follows:

Heat—nil or 12 hours at about 150°C in an oven: the soil was placed directly in the earthenware pot for this purpose: the plastic bag was replaced after treatment.

Ash—nil or 3 tons of ash/acre. Ash was collected from tree bark which had been burned in a hot fire; it was mixed throughout the top inch of soil.

Nutrients—nil or N, P, K, Ca, Mg, Mn, Cu, Cl, Zn, B, Mo, Co. The nutrients were added as the same salts, at the same rates, and in the same manner as were used for basal and for treatment dressings in experiment 2, with the omission of NaH_2PO_4.

Experiment 2—to test the response of karri seedlings on karri-type soil to applications of K, Ca, Mg, S, Mn, Cu, Cl, Zn, B, Mo, and Co fertilizers.

Basal dressings of nitrogen and phosphorus were applied. NH_4NO_3 was applied at 14 cwt/acre in aliquots of 1 cwt/acre to the soil surface at regular intervals. Phosphate was applied as either the sodium or the potassium salt at levels equivalent in phosphate to 4 cwt of superphosphate/acre.

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